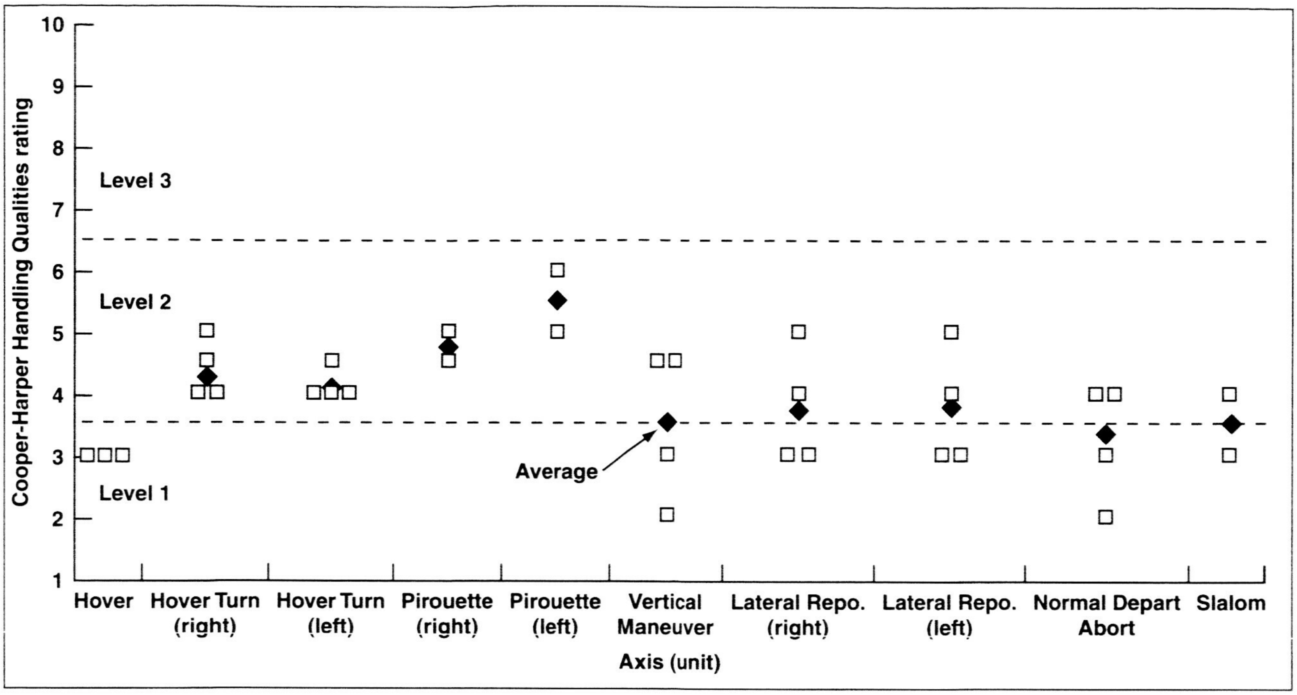

Fig. 2. Handling-quality results from internal ballast configuration in calm winds.

Vision Model Applications to Display Optimization

James Larimer, Jennifer Gille

Managing and controlling modern aircraft in flight remains one of the primary technology challenges of the aerospace industry. The vehicle pilot not only controls the flightpath of the aircraft, but must communicate path objectives to the air traffic control system, and receive and respond to directives from that agency in order to maintain safe and efficient flight. Additionally, the pilot is the manager of the on-board systems that are required for flight. Modern aircraft and aviation systems are highly complex, and for many of these tasks—control, management, and communications—modern display technology has been utilized as the best way to interface the pilot with the vehicle and system. Map displays have replaced compass headings on the aircraft instrument panel, allowing the pilot to see the flightpath information directly in terms that are easily understood and difficult to misinterpret. Air traffic control commands can be visualized directly on these maps. Additionally, the status of on-board systems can be graphically presented to the pilot, reducing his perceptual and cognitive workload, and reducing the potential to misinterpret more traditional system indicators. High-information-content display technology has enabled this transformation of the man-machine interface in aviation. The goal of this effort is to improve the fundamental display technology base in order to make it possible to move lightweight, portable, untethered display technology from the low-cost portable-computing environment to this aviation setting.

Head-mounted displays are currently being developed that use new technology innovations such as liquid crystal on silicon and organic light-emitting diodes. These displays offer revolutionary advancements in weight and power reduction, enabling untethered use with minimal effect on pilot mobility and action in the cockpit. However, there are remaining challenges—image size, resolution, color, contrast, and speed—depending on the display technology. Common expectations about the requirements for these parameters are based on decades of experience with cathode-ray tube (CRT) displays, and not necessarily on perception science.

High-information-content imagery requires broad information channel capacity to the device in order to display fine detail, subtle shading, full color, and continuous motion. However, excess channel capacity for one of these parameters can often be used to compensate for a lack in another. A well-known example of this is the halftones used in printing, where some spatial resolution is sacrificed to enhance tone reproduction.

For several years, Ames has been developing a display optimization tool set known as Visual Display Engineering and Optimization System (VIDEOS). In the investigation of the gray-scale/resolution trade-off for displays, it was found that without dithering, there was no trade-off; there was both a minimum spatial resolution and a minimum number of gray levels required in order to produce an image indistinguishable from a photo-quality version. With dithering, an important trade-off region emerged that corresponds to parameter values achievable by microdisplays being developed for helmet-mounted systems. A summary graph for these results is shown in figure 1. Plot coordinates are spatial resolution (abscissa) and number of gray levels (ordinate). The shaded upper-right-hand regions are below threshold for discrimination. Data points are the threshold results for three observers in the psychophysical study; continuous contours were generated by the computational study using the human vision model and a just noticeable difference JND = 1 for the threshold. Figure 1a shows the results for non-dithered images: the rectangular shape of the below-threshold region indicates the lack of a gray-scale/resolution trade-off. The triangular portion of the contour in figure 1b demarcates the trade-off region for the dithered images. When color dither for displays was investigated, it was found that a considerable savings in computational power could be achieved by dithering in the digital, instead of the luminance, representation of the image, as long as at least six levels of each color were used. These six levels could correspond to what is known as the "browser-safe" palette commonly used for image compression on the Internet.

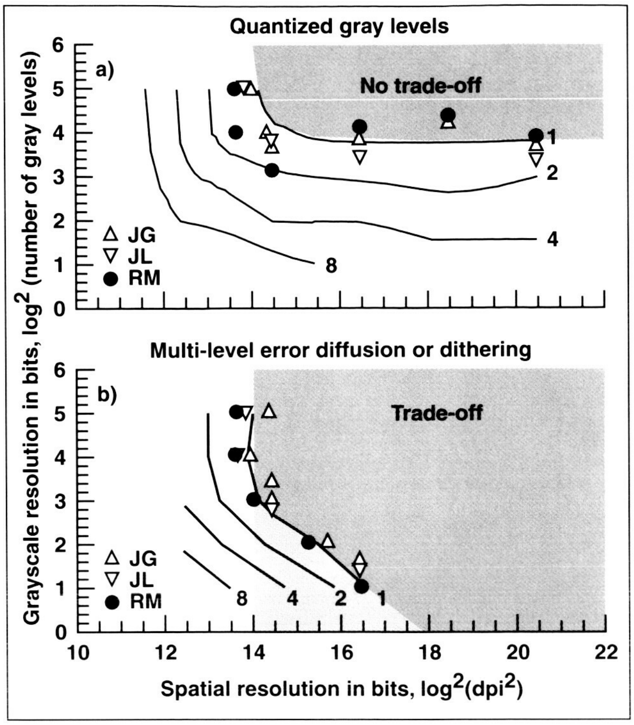

Fig. 1. Threshold contour plots for distinguishing a lower-resolution image from a photo-quality version.

The broad information channel capacity required for high-information content imagery also requires high power outlays to support the device communication needs and to rapidly switch data onto the display device. The ViDEOS team is developing methods for reducing these requirements without sacrificing the visual quality of the images presented to the user. Because these devices act essentially as random access memory units, they provide new opportunities to save communication channel capacity, power, and, ultimately, weight. The unique feature of the Ames approach to this technology problem is that the information quality of the images drives the optimization of the display system. The ultimate goal is to provide new venues of visual information to the pilot thereby improving safety and efficiency.

Figure 2 shows a commercially available near-to-eye display system, suitable for avionics. This lightweight unit can be connected to a flight helmet or even to a baseball cap. This display was manufactured by LitEye™ Microdisplay Systems.

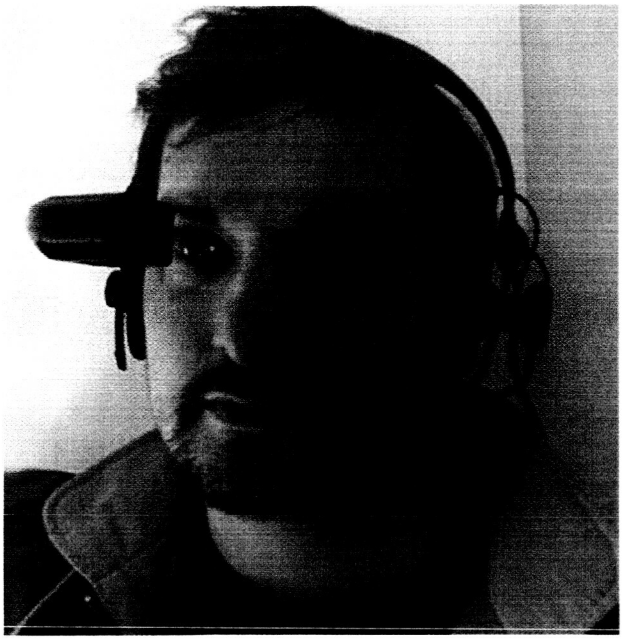

Fig. 2. A near-to-eye display system in use.

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Human Factors Field Evaluation of Cockpit Display of Traffic Information (CDTI)

Rose Ashford, Vernol Battiste

Cockpit Display of Traffic Information (CDTI) is a major departure from traditional ground-based air traffic control and will markedly improve air traffic safety and efficiency, as well as facilitate modernization of the National Airspace System. A prototype CDTI was installed on 12 aircraft (8 Boeing 727's and 4 DC-9's) belonging to the member airlines of the Cargo Airline Association. This initial CDTI (figure 1) displays proximate aircraft relative to their own-ship, assisting flight crews in sighting and identifying traffic "out the window." NASA provided a human factors evaluation of the CDTI to demonstrate whether it would be safe and effective for these initial visual applications, and to provide preliminary results supporting future CDTI applications involving aircraft that are sharing separation responsibility.

Flight scenarios were developed to evaluate flight crew workload, situational awareness, and effectiveness of the CDTI as an aid to visual acquisition and visual approaches. Additional scenarios were developed to demonstrate aircraft station-keeping capabilities assisted by the CDTI. A data collection program was developed and implemented, including the recruiting and training of NASA observers for each flight, and developing protocols for collecting data from the flight deck during the flight scenarios, and for debriefing the flight crews afterward. The evaluation focused on examining the CDTI's effects on flight crew workload and attention, and how normal cockpit procedures were affected by its use.

The planned flight scenarios were flown at Airborne Airpark in Wilmington, Ohio, on July 10, 1999. Results from the evaluation indicate that the CDTI provides significant benefits in flight crew situational awareness, that it aids visual acquisition of traffic, and that it enhances visual approaches. Flight crews found the CDTI easy to use, and they were very positive regarding CDTI as an aid to visually acquiring traffic and determining how close to follow when making a visual approach to a runway. They thought the CDTI helped them maintain awareness of several targets and to reacquire previously sighted traffic, both common requirements in busy terminal airspace. Analysis of the aircraft track data also indicates that the CDTI enhances approach efficiency, although there is much variability in those data, a direct result of the real flight environment. Flight crews were able to manage the station-keeping task satisfactorily.

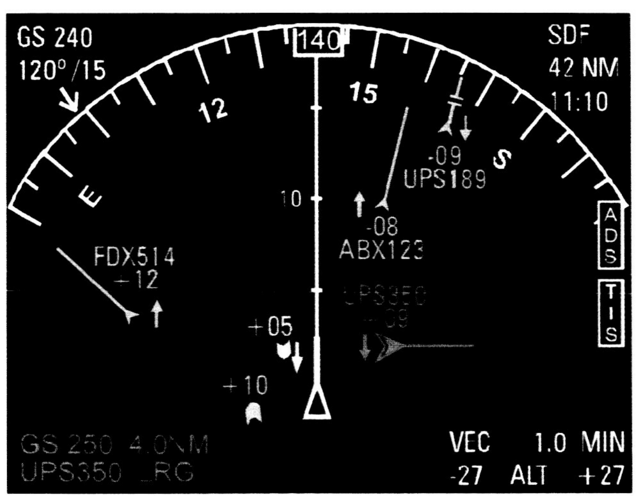

Fig. 1. Cockpit display of traffic information.